Acoustic properties in continental carbonates and their relation to depositional environments, porosity and pore types.

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Sonic velocity logs can provide fast and accurate data on geobodies and their characteristics in the subsurface. The studied quaternary travertines (continental carbonates from Denízlí, Turkey and from Süttő and Budakalász, Hungary) consist of quasi monomineralic calcite ($CaCO_3$). Ultrasonic wave velocities are measured to characterize the acoustic properties of travertine plugs (1.5” diameter), representing four facies-types, being the Sub-horizontal, Reed, Cascade and Waterfall facies. Compressional-wave velocity (V_p) and shear-wave velocity (V_s) are measured with a High Pressure (ultrasonic) Measurement System (HPMS), as function of applied confining pressure with a transducer arrangement (VerdeGeoscience©, Vermont, U.S.A.). The measurements were conducted in a hysteresis loop with confining pressures, ranging between 2.5 and 40 MPa. Sample densities were calculated from dry and saturated weights in combination with their cylindrical volumes. Grain density of the samples was determined with a Micromeritics Accupic 1330 Helium pycnometer and porosity was subsequently calculated from dry and grain densities.
The plugs display a range of velocities (at confining pressures of 40Mpa). Compressional-wave velocity varies between 3695 and 6097m/s, shear-wave velocity between 2037 and 3140m/s. The V_p/V_s ratio ranges from 1796 and 2005m/s, values that are expected for indurated carbonates. This confirms? that artificial compaction was limited. Comparison of the compressional- and shear-wave velocities with ambient Helium porosities (2.8 - 34.7%) showed that the travertine samples from Turkey as well as from Hungary plot along the same velocity transform. Acoustic velocities are dependent on bulk densities, but since there is hardly any change in the grain density of the samples, the bulk density is almost solely dependent on porosity. V_p, V_s and porosity are expected to be inversely proportional. Some samples with similar porosities, however, have different P-wave velocities. Two samples with approximately 20% porosity have V_p values that diverge strongly, respectively 4703 and 5253m/s. In siliciclastic rocks, this range would be explained by differences in composition and mineralogy. The monomineralic nature of the samples in this study, however, implicates that other factors must be involved. It is likely that both fabric and texture of the travertines play an important role in the propagation speed of P- and S-waves. Limited diagenetic alterations and the strong porosity control on the velocities, suggest that pore types (with their typical sizes), pore distributions and their connectivity may explain the variations. Computer Tomography (µCT) shows that rod- to blade-like pores are associated with higher V_p velocities when compared to cuboid, cubic and plate-like pores. The former are larger, often patchy distributed pores that generally provide better connectivity and thus permeability throughout the sample. Acoustic impedance data for the travertines range from 6.7 to 14.9 (10^6 Ns/m³) and are mainly linked to porosity and pore types. Hence, seismic sections in pure carbonates can contain good seismic reflectors that are not caused by non-carbonate intercalations, but relate to geobody boundaries, in which the seismic expression is function of porosity and pore types.